Insecticide horizontal transfer from tephritid male lures containing reduced risk pesticides

Ming-Yi Chou [1, 5], Yu-Bing Huang [2], Horace C. Peng [3],
Yi-Yuan Chuang [3], and Roger I. Vargas [4]

[1] Agricultural Extension Center, National Chung Hsing University, Taichung, Taiwan, ROC
[2] Taiwan Agricultural Research Institute, Council of Agriculture, Executive Yuan, Taichung, Taiwan, ROC
[3] Department of Entomology, National Chung Hsing University, Taichung, Taiwan, ROC
[4] United States Department of Agriculture, Agricultural Research Service, Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, Hilo, Hawaii, USA
[5] Corresponding author, e-mail: mingyichou@dragon.nchu.edu.tw

ABSTRACT

Insecticide horizontal transfer extends pesticide efficacy from individual level to population-wide control through insect food sharing behavior. Social insects and non-social insects with food sharing behavior were most studied subjects for the effects of insecticide horizontal transfer. Very little was known about the food sharing behavior among tephritid fruit fly species, a group of serious pests of fruit commodities in tropical and subtropical area worldwide. Male oriental fruit fly (*Bactrocera dorsalis* (Hendel)) and melon fly (*Zeugodacus cucurbitae* (Coquillett)) are known to feed compulsively on methyl eugenol (ME) and cue lure (CL), respectively. These two semiochemicals in combination with broad-spectrum pesticides, i.e. organophosphate and carbamate, were the standard control tactics in the past decades. With the increasing environmental concerns for the use of broad-spectrum pesticides and that in turn cause the escalation of pesticide resistance indeed promoted the introduction of reduced-risk pesticides in recent years. This type of pesticide with strong bioactivity can cause fruit flies to regurgitate soon after ingesting insecticide-laced attractant. Insecticide horizontal transfer via fruit flies' regurgitated droplets that contained insecticide active ingredient of chlorantraniliprole, acetamiprid, thiamethoxam, spinosad and fipronil were demonstrated in this paper. Field trials conducted in Hawaii demonstrated that not only male but also female *Z. cucurbitae* population density reduced significantly in the area treated with CL-fipronil. Laboratory studies further confirmed that droplets of

regurgitated CL-fipronil caused high mortality in both male and female flies that received the regurgitated CL-fipronil within 24 h. Laboratory studies conducted in Taiwan demonstrated that exposing *B. dorsalis* males to individuals fed on ME-spinosad and ME-thiamethoxam caused significantly higher mortality in male flies than that received ME-chlorantraniliprole and ME-acetamiprid treatments. Significantly higher female fly mortality was recorded in contacting flies that fed on ME-spinosad. Data from cage studies demonstrated that male flies did not show preference among ME-spinosad, ME-thiamethoxam and ME-acetamiprid regurgitants. The results from this study demonstrated that male annihilation technique using reduced-risk pesticides are suitable alternatives for organophosphates. The potential of employing insecticide horizontal transfer in fruit fly management was also discussed.

Keywords: Tephritidae, insecticide horizontal transfer, fipronil, spinosad, thiamethoxam, chlorantraniliprole

INTRODUCTION

Tephritid fruit flies (Diptera: Tephritidae) are important economic and quarantine pests of fruits and vegetables in many parts of the world. Current options for managing fruit fly pests in agriculture environment include sanitation, cover spray, proteinaceous baits, and male lures. Cover spray provides temporary control but has little long-term effect. Repeat applications of cover spray are not only costly and labor intensive, but also place significant risks to non-target species in the environment and increase the risk of pesticide resistance escalation [4, 10]. In recent years, the concept of area-wide management approach has gradually shifting growers' practice from single tactic cover spray to multiple tactics integrated pest management [18].

Male annihilation technique using semiochemicals

Attract-and-kill method using insecticide-laced male lures can reduce fruit fly populations by removing large number of males that reduce their mating potential that subsequently decrease crop damage. Successful control of fruit fly populations with attract-and-kill male mass trapping was demonstrated in oriental fruit flies (*Bactrocera dorsalis* (Hendel)), melon flies (*Zugodacus cucurbitae* (Coquillett)), and Mediterranean fruit flies (*Ceratitis capitata* (Wiedemann)) [5, 17]. Methyl eugenol, cue lure, and biolure are semiochemicals that attract male oriental fruit fly, melon fly and Mediterranean fruit

fly, respectively. Male annihilation using organophosphate-laced attractant was widely applied to control insect pests in agricultural production area in the past decades. With the increasing environmental concerns for using broad-spectrum pesticides and that in turn causes the buildup of pesticide resistance indeed promoted the introduction of reduced-risk pesticides in recent years. This type of pesticide with strong bioactivity cause fruit flies to regurgitate soon after ingesting insecticide-laced attractant. Insecticide horizontal transfer via fruit flies regurgitated droplets was first observed in Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) and later documented in *Z. cucurbitae* and *B. dorsalis* [3, 16].

Pathways of insecticide horizontal transfer

Toxic baits that exploit the recruitment and food-sharing behaviors of social insects are effective control measures with the benefits of reducing the amount of insecticide required and the risk of affecting other organisms during pest control application. Insecticides are transferred horizontally through food sharing to pest colonies and hence expand the control from individual to population level. Foraging members of an insect population can transfer insecticide horizontally to the rest of the colony through feeding on regurgitated food, grooming and contacting poisoned individuals [13]. Insecticides with strong bioactivity which cause insect to regurgitate or excrete shortly after ingesting toxin are good candidates for horizontal transfer to facilitate the transfer of toxicants in pest population [9,15]. The toxic regurgitant and feces are attractive to the conspecifics and provide secondary mortality occurred away from application site. It increases the effect of insecticide to area where the insects aggregate. Insecticide horizontal transfer is also recorded in German cockroach (*Blattella germanica* (L.)), grasshopper (*Melanoplus sanguinipes* (Fabricius)), and yellowjackets (*Vespula pensylvanica* Rohwer) [2, 12, 14]. In these studies, horizontal transmission of insecticides occurred through cannibalism, coprophagy (ingestion of feces) and necrophagy (ingestion of dead conspecifics) in both laboratory and field settings.

Regurgitation and insecticide horizontal transfer in tephritids

Little is known about the mechanism of regurgitation and the effect of insecticide horizontal transfer in tephritid fruit flies. It is believed that such behavior condenses the nutrient content by evaporation of excess water. Observations show that *B. tryon*i often

imbibe droplets of regurgitants from feeding surface [6, 7]. *C. capitata* evaporates excess water content in the liquid food source by repeatedly re-ingesting droplets of regurgitated liquid by holding droplet between labellar lobes [8]. Regurgitation has been associated with pheromone-marking in Caribbean fruit fly (*Anastrepha suspensa* (Loew)) and its male offers mating to trophallaxis substance in *Anastrepha striata* [1, 11].

Bull (2010) documented the first case of insecticide horizontal transfer in tephritid fruit flies. Male flies of *B. dorsalis* and *Z. cucurbitae* are known to feed compulsively on methyl eugenol (ME) and cue lure (CL), respectively. Field trials conducted in Hawaii demonstrated that not only male but also female *Z. cucurbitae* population density reduced significantly in the area treated with CL-fipronil. Laboratory studies further confirmed that droplets of regurgitated CL-fipronil caused high mortality in both male and female flies that received regurgitated CL-fipronil within 24 h. Laboratory studies conducted in Taiwan demonstrated that exposing *B. dorsalis* males to individuals fed on ME-spinosad and ME-thiamethoxam caused significantly higher mortality in male flies than those received ME-chlorantraniliprole and ME-acetamiprid treatments. Significantly higher female fly mortality was recorded in contacting ME-spinosad-fed flies. Data from cage studies demonstrated that male flies did not show preference among ME-spinosad, ME-thiamethoxam and ME-acetamiprid regurgitants. The results from this study demonstrated male annihilation technique using reduced-risk pesticides are suitable alternatives for organophosphates. The potential of employing insecticide horizontal transfer in male annihilation program expands the effect of insecticide to the population level.

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